RAILWAY APPARATUS

WESTINGHOUSE ELECTRIC & MANUFACTURING CO.
PITTSBURG, PA.

ELECTRIC RAILWAY APPARATUS.

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Introduction.

THOUGH but a comparatively brief period has elapsed since the introduction of Electricity into street car service, this "unseen force" has had time and opportunity sufficient to clearly demonstrate its claim of superiority to other methods of propulsion. In fact, the advantages of the electric system, in its application to street railways, are so quickly apparent that the real question open to debate is, not *what motive power*, but *what make of apparatus!*

In this descriptive catalogue of Electric Railway Apparatus, we shall give a brief sketch of our Single Reduction Motors, Multipolar Generators, and some of the more important apparatus necessary for the car equipment, passing the less important details and the switchboard apparatus with the mere statement that each detail has received its due share of attention in our endeavor to bring all parts of our railway system to the same high standard of unsurpassed excellence.

In the mechanical construction of both motors and generators the question of providing an ample margin of strength above the rated or normal capacity has been carefully considered, and we have not spared material when it was necessary to secure this all important requisite, but have made

certain of the best results, even under the severe strains to which apparatus is subject in street railway practice.

In electrical design we have combined high efficiency with thorough insulation and good workmanship — a union without which the economical operation of an electric railway plant would be impossible.

Although we have been in the electric railway field but a short time, comparatively, our apparatus has earned an exceptional reputation, and we can point to a large number of roads which although originally equipped with machinery of other makes, have since transferred their patronage to us, thus most emphatically acknowledging the superiority of our apparatus.

We have received so many letters from our patrons, expressing the satisfaction given by our railway apparatus, that it has seemed proper to print some of them in a "Book of Testimonials," which we will gladly furnish to any one who may desire us to do so.

Respectfully,

Westinghouse Electric & Manufacturing Co.

PITTSBURG, PA., May, 1893.

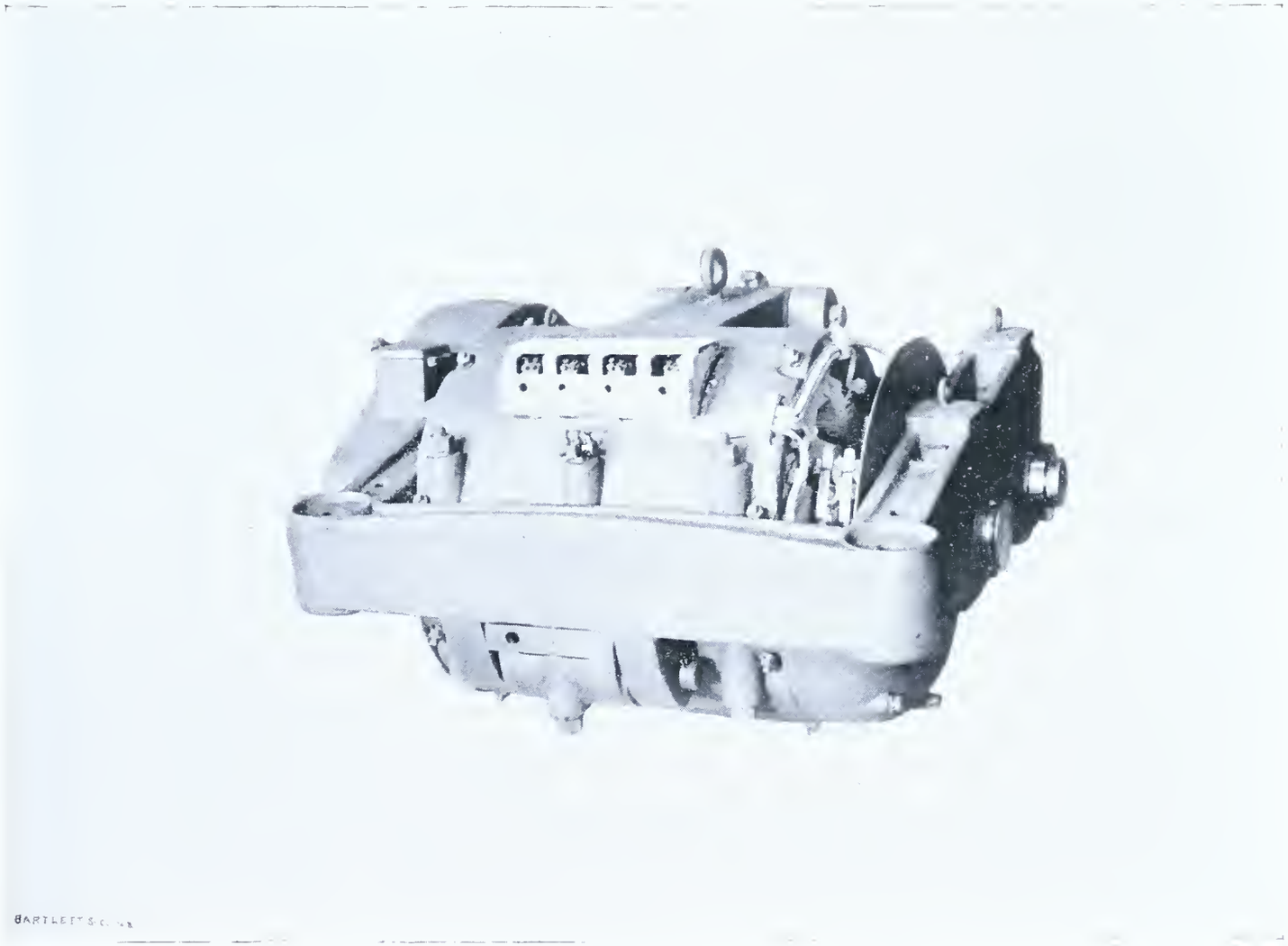

FIG. I. No. 3 SINGLE REDUCTION RAILWAY MOTOR.

Motors.

IN the design and construction of Railway Motors there are four points which demand particular attention if the motor is to be reliable in use and economical as regards expense of maintenance. The first of these is the strength of each individual part as well as of the complete machine; the second is accessibility for inspection and repair — the importance of this qualification will be realized when the naturally inconvenient location of the Street Car Motor is considered. The third point is perfect insulation of the various windings. We have given this detail of construction most careful attention, and our experience in dealing with high voltages has led us to adopt a novel form of Armature and Fields, which permit of the most perfect insulation of all windings. The fourth is the protection of all the delicate parts of the apparatus from moisture, snow and dirt, and from extraneous physical injury. The provisions which are made to cover these four points (which apparently had been completely disregarded by other manufacturers) together with the exacting tests given each motor before shipment, have made possible the great success of the Westinghouse Electric and Manufacturing Company in the Street Railway business.

For ordinary street car work, we manufacture Standard Single Reduction Railway Motors of three capacities, viz: 20, 25 and 30 horse power. For the heaviest work, such as required by Electric

Locomotives, we build motors of 40 and 50 horse power capacity and larger, designed for either slow or high speed. The motors are equally well adapted to four or eight wheel cars, and may be used on any gauge, from 3′ 6″ up. We are thus able to meet the requirements of all conditions of electric service. The 25 and 30 horse power equipments are adapted to roads where, owing to severe grades, high speeds, heavy traffic, or other causes, the work required of the motors is above the average encountered in electric railway practice.

With two of these larger motors under double truck cars, one and two trailers are successfully handled on a track having severe grades and many curves.

In form and general construction the three standard sizes are similar, and the descriptions and illustrations which follow will apply to all.

In figure I is presented a perspective view of our four pole Single Reduction Motor; while figure II gives another view, which brings out very prominently the manner in which the gears are encased and shows the interior arrangement of the motor details. The construction of the motor can readily be comprehended by referring to figure III, where are shown the castings which form the field magnets and frame of the motor.

The lower part of the motor is entirely shut in, thus completely protecting the armature and field coils from moisture, snow and dirt, and making the use of pans and curtains unnecessary.

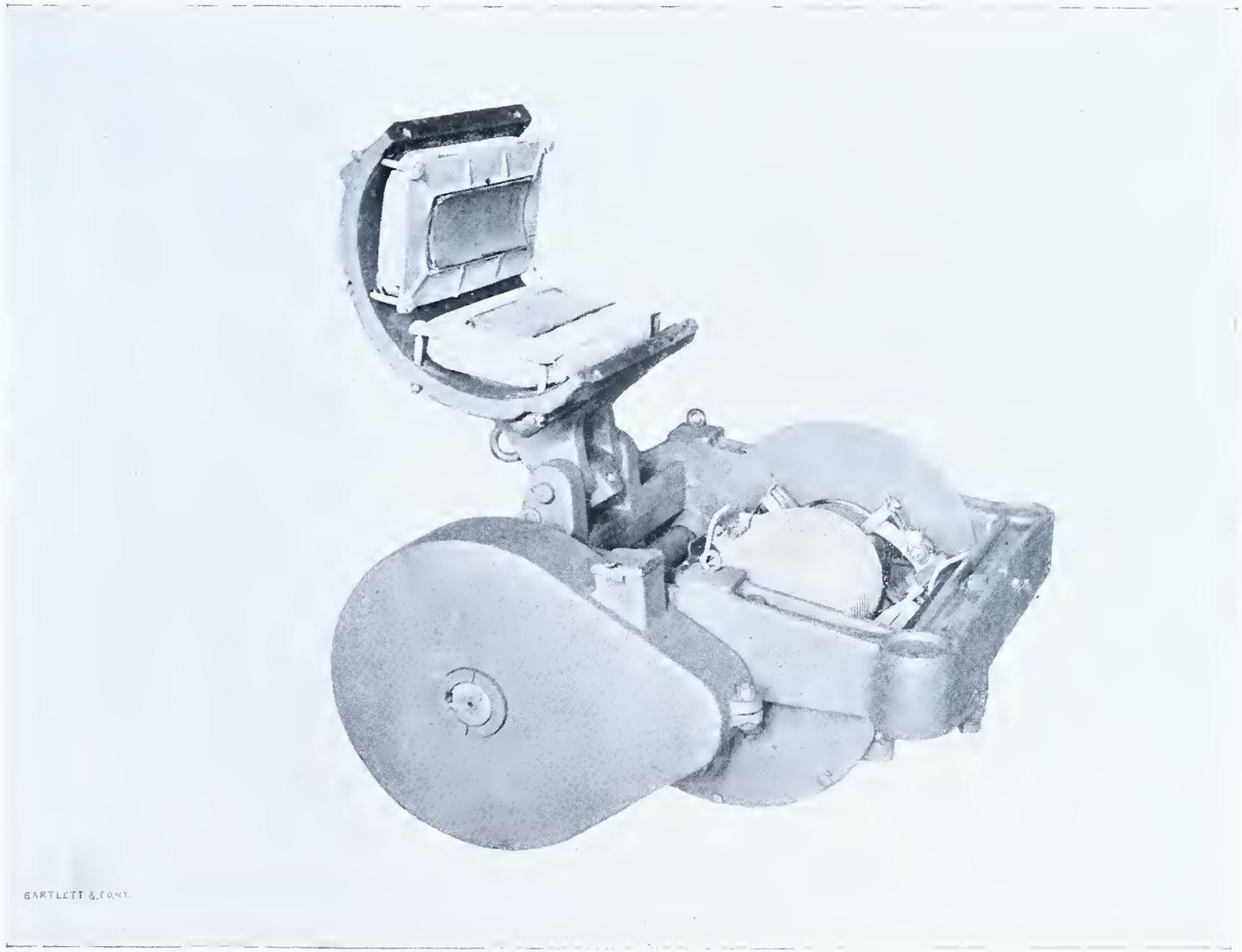

FIG. II. No. 3 SINGLE REDUCTION RAILWAY MOTOR, OPEN.

The Field.

THE motor has four pole pieces, which project radially from the interior of a cylindrical yoke. Formerly engineers were divided in their opinions as to the relative merits of four-pole and two-pole motors, but latterly the advantages of the former type are being recognized, for the four-pole field is lighter than the two-pole, and offers a shorter path for the magnetic lines of force. It also allows the use of a circular yoke, which gives the greatest mechanical strength and is lighter, for a given cross section, than any other form. The Westinghouse motor, combining, as it does, the multipolar field and the two-circuit armature, embraces the important advantages of both types of machines. The field coils are separately wound on lathes, thoroughly insulated, and then slipped over the pole pieces, and held in place by flat brass rings bolted to the yoke. The yoke is in two parts, divided by a horizontal plane through the armature shaft.

The cast iron frame in which the motor is mounted is a distinguishing feature of the Westinghouse motors. This frame is rectangular, in one casting, and made sufficiently strong to withstand the greatest strains. It extends entirely around the motor, and is suspended at two corners on springs, which distribute the strains and prevent abnormal wearing of the bearings.

By means of the frame the armature shaft and car axle are maintained in perfect parallelism, and consequently perfect meshing of the gears is assured. Easy access to the field coils and armature is secured by the hinged arrangement of the fields, clearly shown in figure No. III. To remove a field coil the upper half cylinder, or the lower half, as the case may be, is swung back, the coil unbolted and slide off its pole piece entire without molesting its windings.

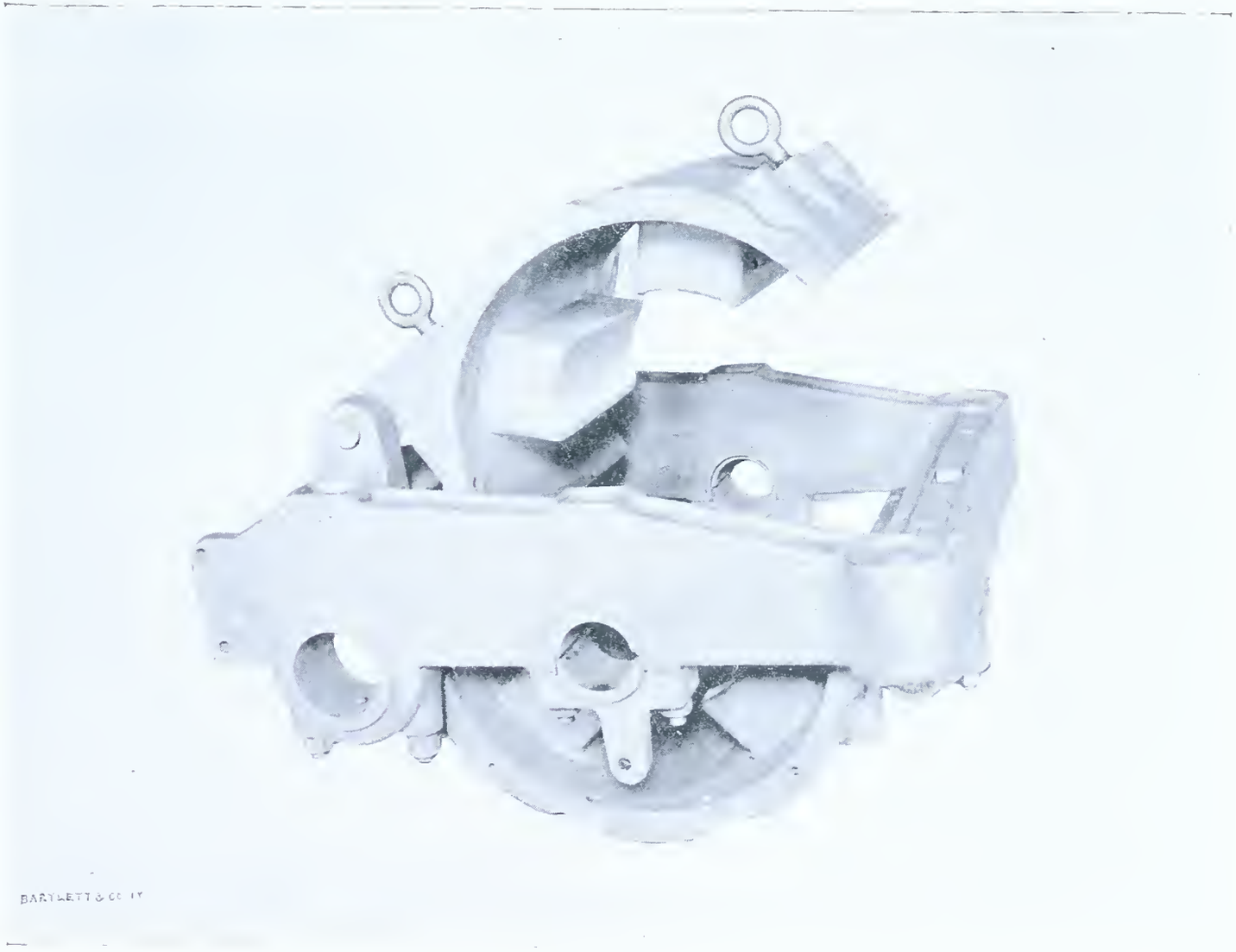

FIG. III. No. 3 SINGLE REDUCTION RAILWAY MOTOR CASTINGS.

The Armature.

REALIZING that the most vital part of any street railway motor is the armature, and that here good mechanical and electrical construction is absolutely necessary, we have given this matter the attention which such an important feature demands, and, as a result, have secured an armature which is extremely simple in form, and at the same time practically indestructible. The armature is of the drum type. The core is built up of thin sheet iron discs placed between thicker end-plates, and the whole keyed directly to the shaft.

No non-magnetic spider is necessary. The use of such a spider is a fault which cannot be avoided in the ring armature. The difficulty is that the material of the spider and the iron of the core have different coefficients of expansion. As the load increases and decreases the armature is constantly expanding and contracting, by reason of the change in temperature. The difference in the amount and rate of expansion of core and spider causes the latter to work loose. It is essential that the armature be rigidly connected to the shaft, and that it remain so under all changes of temperature, but this rigid connection can be secured only by the use of a drum core.

The drum armature is keyed directly to the shaft and hence is truly centered from the beginning to the end of its construction. Some of its other advantages are:—comparatively small size, accurate mechanical balance and solid construction.

The periphery of the completed armature core presents a number of grooves running parallel to the shaft, as shown to the right in figure IV. The core with the coils in place is shown in the center, and the completed armature to the left of the same figure.

The armature is NOT hand wound. The coils are wound on a lathe, and then individually wrapped with heavy insulating tape before being handled by the winder, who only fits the coils to the armature grooves. It is thus seen that the cotton insulation of the wires is not touched during the winding. The casing of the coil allows it to be slipped into the grooves as a whole, no individual wire being disturbed. The insulation separates each coil from its neighbor, so that there can be no contact between the wires.

There are no crosses, except of one coil on another, where the quadruple insulation affords ample protection. In the ordinary drum armature individual wires cross each other frequently, and for the necessary insulation at these points absolute dependence is placed on the care of the workman. *We do not depend upon the judgment of the winder for the thorough insulation of our armatures.*

As the coils are put on, the insulation is subjected to a thorough test, and a coil is rejected unless it stands a pressure of 1200 volts. Tests are made at the completion of every process of

FIG. IV. No. 3 SINGLE REDUCTION RAILWAY MOTOR ARMATURES IN CONSTRUCTION.

construction, so that each armature, from the time its winding is begun until turned out complete, receives no less than twenty-three separate tests.

Mechanically the coils are held rigidly in the grooves and no motion is possible. The severe strains, due to the reaction between field and armature when starting suddenly under a heavy load, are very disastrous to the surface wound armature, tending to displace and loosen the wires, and thus injure the insulation. The wires on our armature cannot yield to this tendency.

To protect the armature from injury in shipping, handling, etc., outside insulation is put on and held in place by band wires. These bands are not necessary to hold the coils, as the latter are firmly fixed in the grooves, but we think that the severe service required of a railway motor makes this additional protection advisable.

Methods of Connection.

THE style of connection is such as to secure what is known as the two-circuit winding, which means that there are but two paths for the current through the armature. By this method of connection the whole winding is utilized, despite the fact that we employ but *two brushes with a four-pole field.*

The armature circuits cannot become unbalanced; that is, one portion of the circuit cannot carry more current than another, and thereby cause excessive heating, waste of energy and injury to the insulation. This may be explained as follows:

When the wear of the bearings allows the armature to approach slightly nearer the lower pole pieces the effect of these poles becomes relatively greater than that of the upper ones. If more than a two-circuit winding were used a part of the winding would do more than its share of the work, owing to the unequal action of the different poles. With the two-circuit winding, however, each pole affects each winding to the same extent, so that no unbalancing is possible. To emphasize this fact

still further, we may state that either half of the field of our motor may be removed and the armature will still revolve from the action of the other two poles. This may be done without shifting the brushes, and without causing sparking, since the position of the neutral points is not changed.

The fact that no high tension wires cross each other, and the prevention of the heating due to the piling up of the wires around the shaft, do away with the objections to the drum armature; at the same time all of its good points are retained.

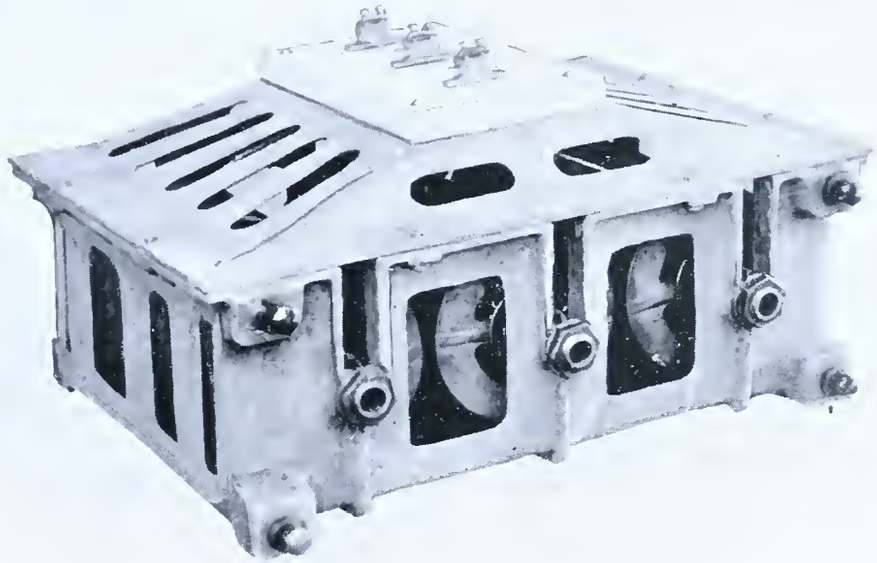

FIG. V. STREET CAR DIVERTER.

The Car Equipment.

THE motors under a car may be reliable, but the details of the car equipment must be equally good, otherwise the car may be laid up for repairs a large part of the time through faults in no way traceable to the motors. Realizing this, we have carefully elaborated the two pieces of apparatus next most important to the motors, viz, the *Current Diverter* and the *Controlling Stand.*

Our improved form of Current Diverter consists of a small wrought-iron frame, containing coils of flat iron wound compactly between sheets of mica. The function of the diverter is, primarily, to reduce the current on starting, so that the car may be easily and gradually gotten up to speed and the motors saved from sudden and injurious jerks; but, furthermore, the diverter allows variation in the speed of the car, and permits slow running through crowded streets. The frame containing the coils is secured under the car-body where it is not seen, and being strong, simple and fire-proof, it requires no attention other than the occasional inspection of its connections.

Our new Series Multiple Controller allows a more economical utilization of the current than does the style usually found on all existing electric roads. It starts the motors with their fields and

armatures all in series, thereby avoiding a sudden start; the resistance is gradually reduced until it reaches a minimum, on the last notch, when the motors are in parallel. A road substituting new controllers for the old style will find that they save a large percentage of the energy formerly used for operating the same cars.

The Stand is placed on the platform of the car where it can be quickly and easily inspected. It is provided with water-tight top and covering. One of the objects in the design of this controller has been to make it perfectly fire-proof, thereby insuring against injury when in the hands of inexperienced and ignorant men. This end has been attained by using for construction no more combustible materials than brass, amyloidon and vulcabeston. The flash which must always occur when the circuit to the motors is opened takes place between brass tips at the ends of the contact strips. As these tips are cheaply replaced the controller is practically indestructible.

An ingenious ratchet wheel at the top of the cylinder distinguishes the different positions of the switch, making it possible for the controller to be operated intelligently, even in perfect darkness. The motorman thus not being compelled to fix his eyes on the switch, is enabled to keep a better look out ahead.

A single revolution of the handle passes over all the notches of the controller. The reversing is done by a separate switch, the handle of which projects from the side of the stand, as shown in the cut on the opposite page.

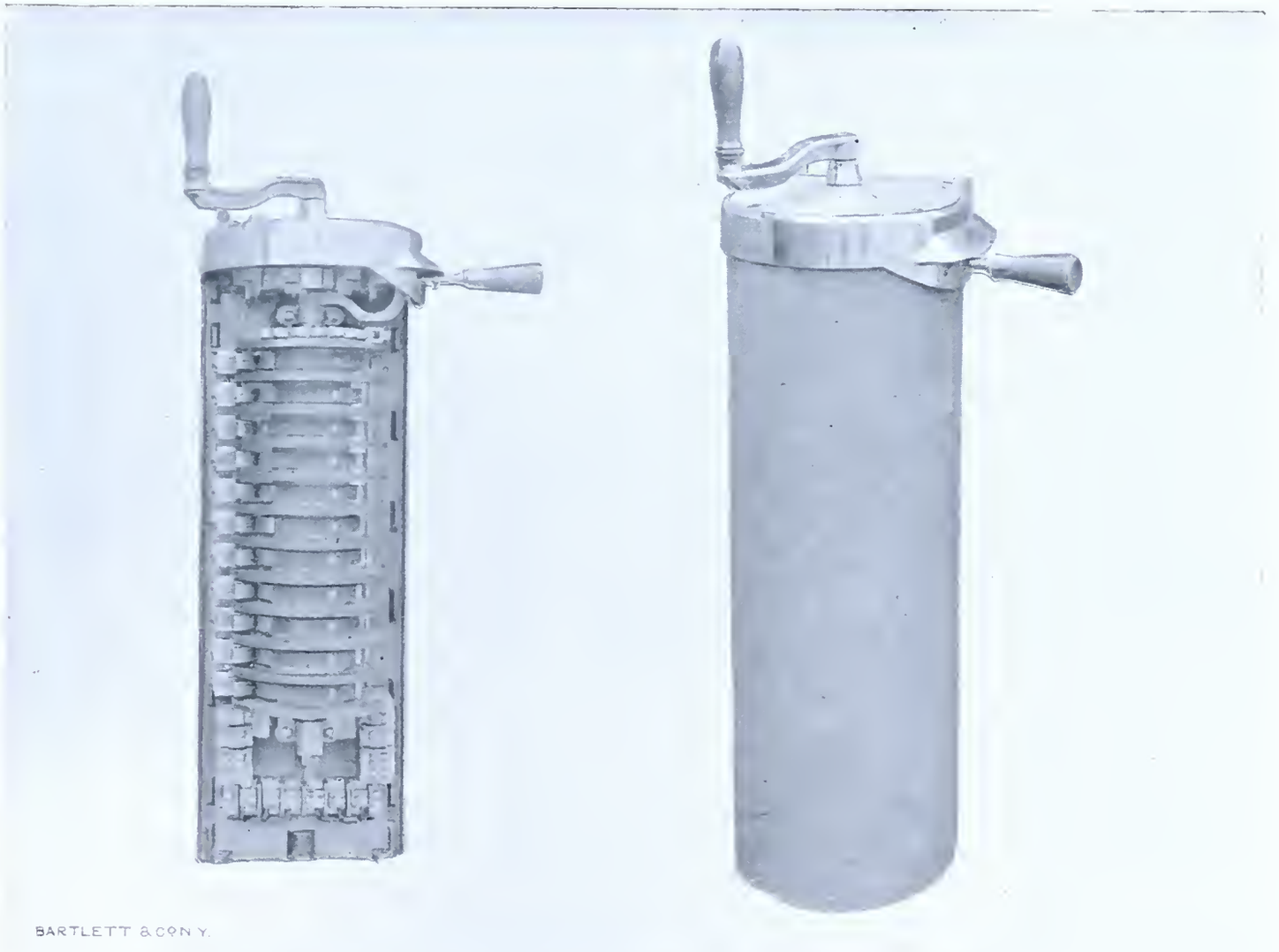

FIG. VI. SERIES MULTIPLE CONTROLLING STAND, WITH AND WITHOUT COVER.

Generators.

THE Generators manufactured by the Westinghouse Electric & Manufacturing Company are without doubt the best in the market. These machines are designed to be either belt-driven or direct-connected to the shaft of the engine. They are self-oiling, self-exciting, perfectly self-regulating, and, after being started, completely self-attendant.

The Railway Generators are wound for a nominal voltage of 500, but, having a rheostat in the field circuit, the potential can be raised to 600 volts without undue heating, and even 50 per cent. over-loads will be borne for short periods without injury to the machine.

Before shipping, every generator is set up and run under conditions similar to those it is intended to meet in actual practice, and no machine is allowed to leave the factory unless enduring tests of its mechanical and electrical perfection.

A common difficulty with railway generators is sparking at the brushes, which is usually caused by the points of commutation shifting with variations in the load. It has been our aim to

overcome this trouble, and that we have done so is proved by the fact that after the brushes have once been adjusted, further change in their position is unneeessary, no matter how sudden or how great may be the variations in the amount of current supplied by the generator. One of the tests to which we subject these generators is to throw on and off heavy loads, always leaving the brushes in the same position. No sparking is caused even by a current in excess of the rated capacity of the machine, and it is impossible to distinguish, by watching the brushes, whether the generator is loaded or not.

The machines are of the Multipolar Type, reversible on their bed-plates, and can be run equally well in either direction by making a slight change in the connections.

The bearings are self-oiling. A large reservoir below each box holds a quantity of oil which is carried up on the bearings by oil rings revolving about the shaft. In this manner the bearings are automatically oiled by the motion of the shaft, and they require no attention beyond a periodical examination and renewal of oil.

Automatic alignment is secured by the use of ball bearings, which adjust themselves and can never bind on the shaft.

The supports for the bearings are cast in one piece with the lower half of the field, a construction which gives great strength and rigidity to the bearings, and secures the greatest possible freedom from vibration.

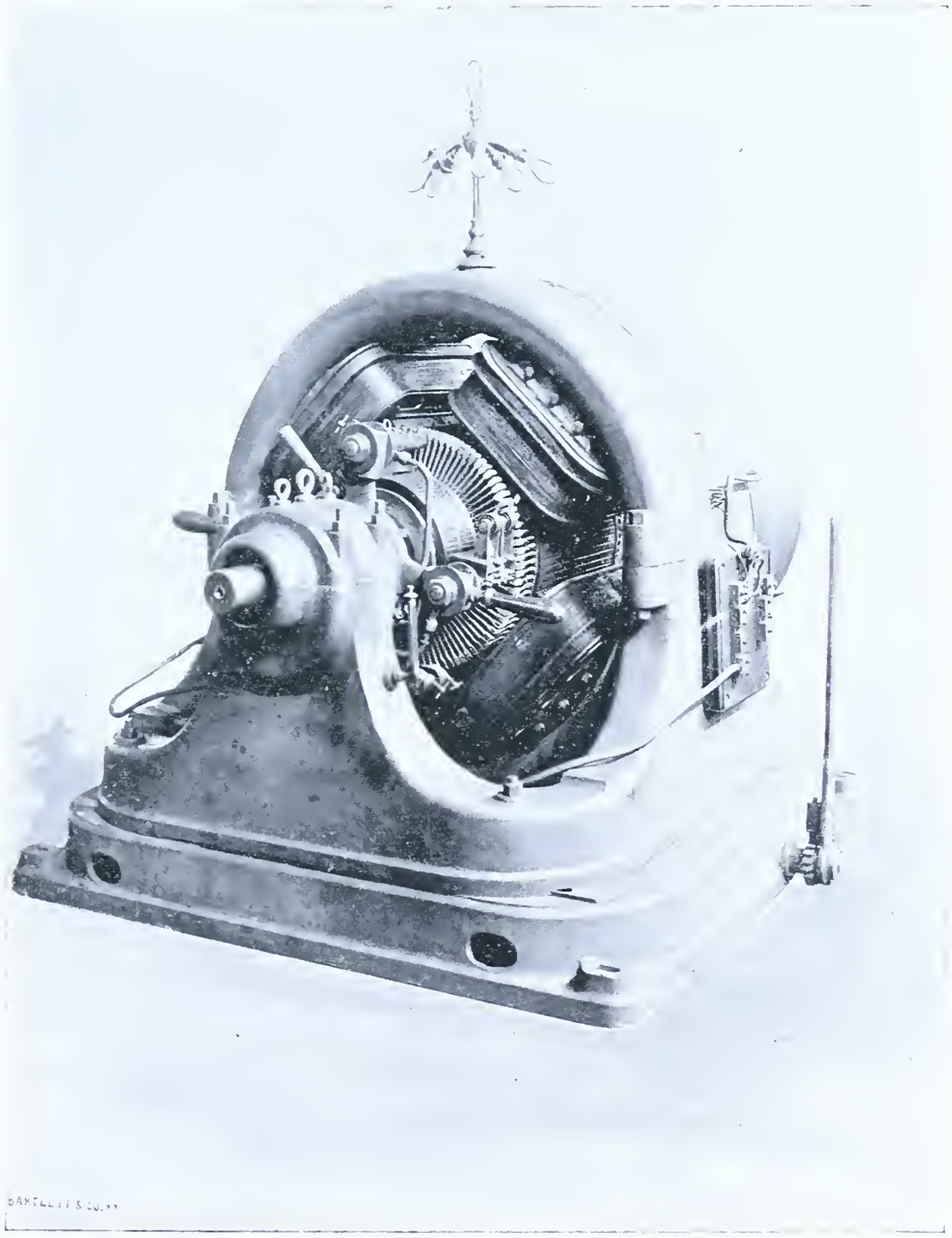

FIG. VII. 100 H. P. MULTIPOLAR BELT DRIVEN RAILWAY GENERATOR.

There are four sets of carbon brushes used on our Railway Generators. Each brush is held in an independent holder, hence any single brush can be raised from the commutator without disturbing the others, and each, having its own spring, may be perfectly adjusted. The diametrically opposite brushes are of the same polarity and are connected together. The rocker-arm of the brush holder is of rigid construction, and the different parts are perfectly insulated: it is designed so that it will adjust all the brushes simultaneously.

The larger sizes of our Generators have slight differences in design, due mainly to the increased size of all parts. As will be noticed in the cut of the 700 H. P. generator, shown on page 49, the shaft of the belt-driven machine has three very long bearings, one of them being placed outside the pulley, thus avoiding flexural strains on the shaft. A special arrangement, consisting of a worm and wheel, as shown, is provided for adjusting the brushes.

After a generator has been placed on its foundation the eye-bolt in the top field is removed, and a handsome electrolier substituted.

Our Railway Generators are all standard machines, so that any part can be perfectly duplicated by us with the least expenditure of time and money.

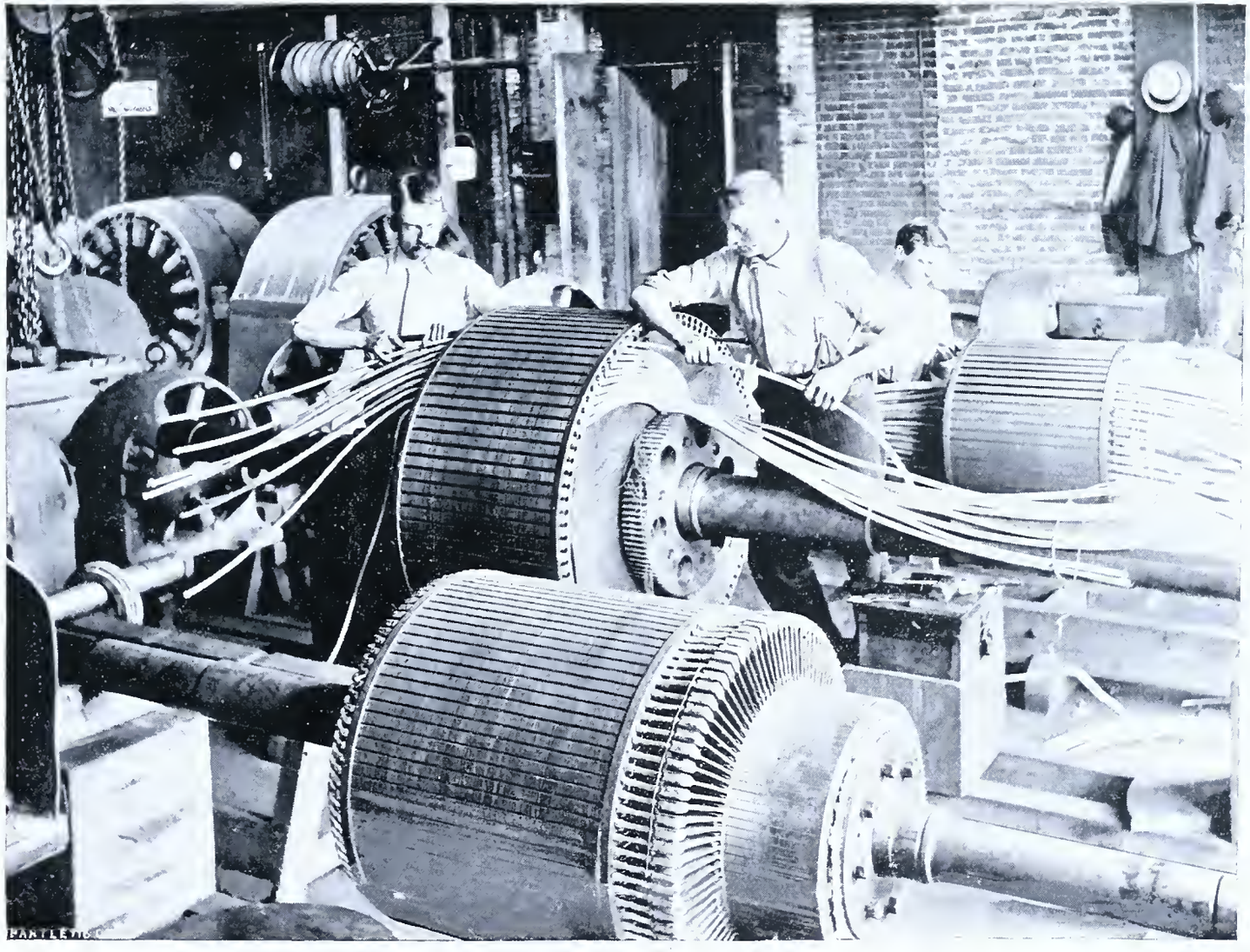

FIG. VIII. WINDING OF MULTIPOLAR RAILWAY GENERATOR ARMATURE.

The Armature.

A DISTINCTIVE feature of our Generator is the construction and winding of the armature. The two-circuit winding, and all the other marked advantages of our motor armatures, have been adopted with slight modification in our multipolar generators.

The core is built up of thin discs of soft iron, punched around their circumference with oval holes. The discs are then properly insulated, forced together under pressure, and rigidly keyed to the shaft.

The oval apertures being superimposed one above the other, result in forming grooves which extend parallel to the shaft the entire length of the armature. In every groove are placed tubes of insulating material, through each of which is run a stranded cable, or copper wire.

The accompanying photograph, taken in our winding room, will illustrate the ease and simplicity of winding.

The old method of constructing drum armatures was to wind the wire upon the outside of the armature core until the latter was completely covered with wire, often to the depth of three or

four layers; these wires were prevented from flying out under the influence of centrifugal action by bands, or binding wires, which surrounded the armature.

In our present form of armature, as explained, each wire is thoroughly protected by insulating material, and then rigidly secured *beneath* the iron, so that there is absolutely no possibility of its coming loose, or making contact with another wire.

The winding is of the simplest form possible, as each coil consists of but a single loop of wire. The simplicity is particularly noticeable at the ends of the armature, where the wires, instead of being overlapped and bunched together, stand out from the core and from each other, thus allowing free circulation of air around every conductor. No wires, having a large difference of potential, are adjacent to one another.

The necessary voltage is secured by revolving a comparatively small number of coils of wire in a powerful magnetic field, rather than by using a large number of coils and weak field, as is the usual practice.

The small amount of wire on these armatures accounts, in great measure, for the absence of sparking at the brushes, and the fixed position of the points of commutation under variations of load. No matter how great the current in the armature conductors the field is always powerful enough to overcome the effect of their cross-induction, and consequently the lead does not have to be changed.

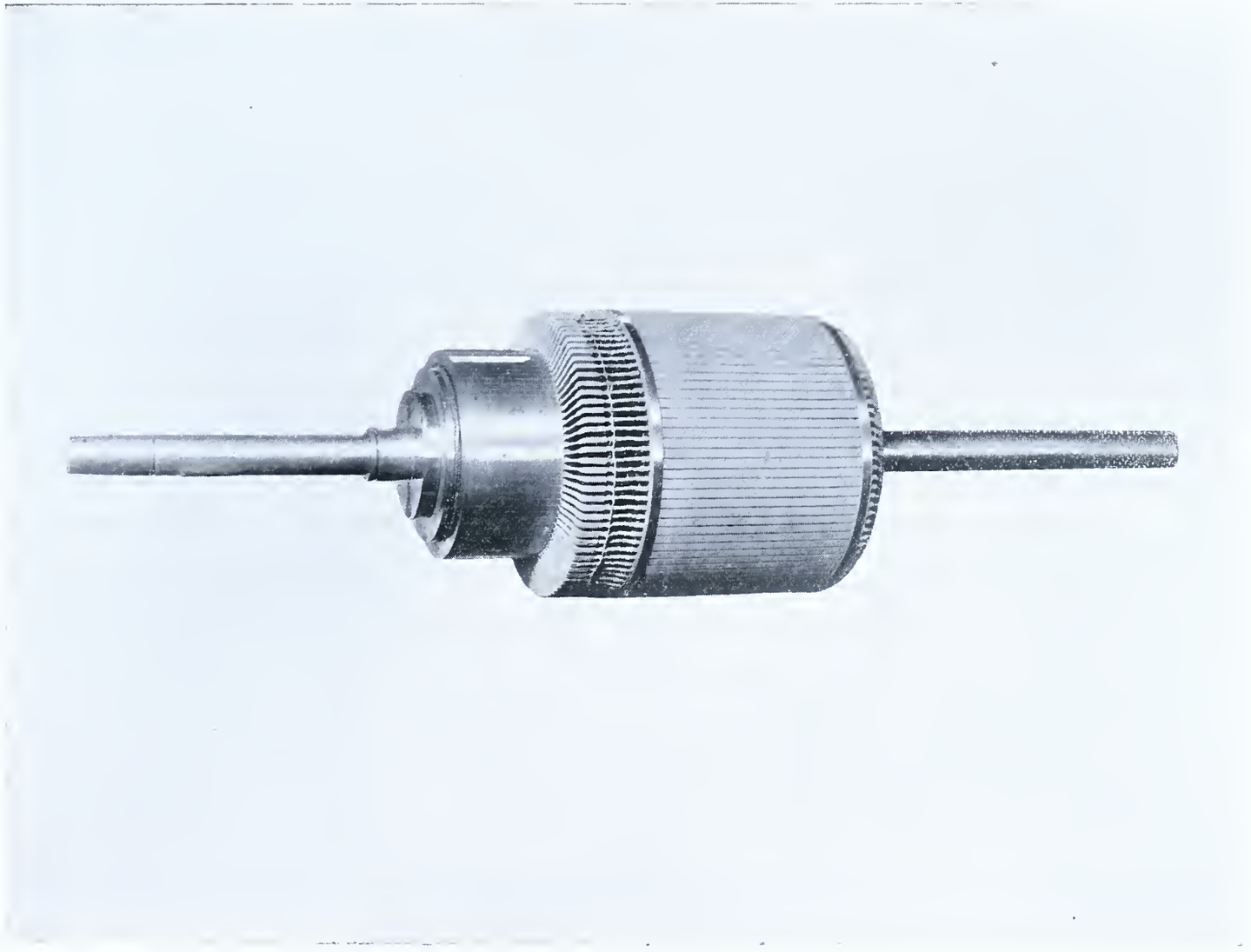

FIG. IX. MULTIPOLAR RAILWAY GENERATOR ARMATURE, COMPLETE.

The commutator is designed on truly mechanical principles. It is long and massive, affording ample contact for the brushes. The segments are of the purest copper, carefully insulated from one another by the best quality of mica.

Owing to the simplicity of construction, the orderly arrangement of the wires at the ends, and the absence of all bands or binding wires on the surface, our finished armature presents the attractive appearance shown on page 45.

The Field.

THE field consists of a circular yoke, with four inwardly projecting pole pieces, which are built up of thin sheets of iron. The exciting coils are compound wound on metal bobbins. One bobbin is slipped over each pole piece and secured in place by bolts. The bearings and field divide along a horizontal plane, thus allowing the removal of the upper half of the field, and permitting access to the coils and armature.

We have given most careful attention to proportioning the windings of our generators, and have succeeded in so compounding them, that, as the current supplied to the line increases, the voltage rises sufficiently to make up for the loss or "drop" in line, or for a variation in the speed. This action, which is due to the effect of the series coils, insures a more nearly uniform voltage at the cars, thus enabling them to give correspondingly better service.

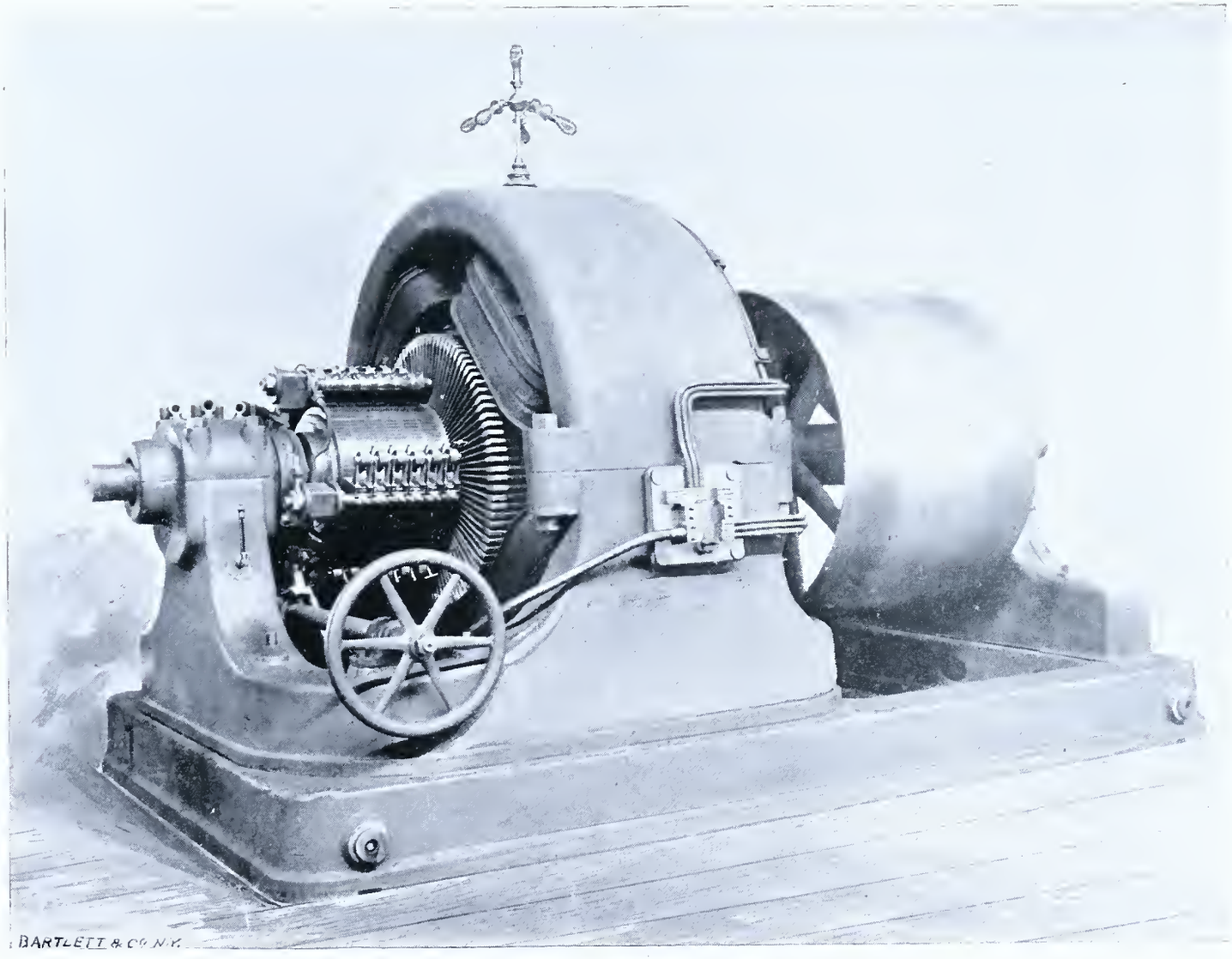

FIG. X. 700 H. P. MULTIPOLAR BELT DRIVEN RAILWAY GENERATOR.

Belt Driven Generators.

THESE machines run at from 300 to 750 revolutions per minute, depending upon their size. They are mounted on ways, upon which they may be moved back and forth when it is necessary to increase, or decrease, the tension on the driving belt. Their large electrical output for their weight, the flexibility of belt driven generators — in that they can be thrown from one engine to another in case of break down — and the very high commercial efficiency, makes them a deservedly popular type of generator for railway work.

The table on the next page gives the various details concerning our standard belt driven railway generators:

MULTIPOLAR DIRECT CURRENT BELT DRIVEN GENERATORS.

Machine.	Capacity.	Output.		Dimensions Over All.					Weight in Pounds.			Speed.	Pulley.	
500 Volt D. C. Generator.	Horse Power.	Amperes.	Volts.	Length of Shaft.		Width of Bed-Plate.		Height Over Eyebolt.	Net.	Largest Gross Piece.	Gross Boxed for Shipment.	Speed R. M. P.	Diameter.	Face.
No.				Ft.	Ins.	Ft.	Ins.	Ft. Ins.					Ins.	Ins.
00	80	120	500		72		$58\frac{1}{2}$	4 11	8809	3393	10010	750	26	10
0	100	150	500		$87\frac{1}{2}$		$64\frac{1}{4}$	5 4	12000	4500	13250	750	26	14
1	150	225	500		$92\frac{1}{4}$	5	8	5 9	16500	4900	18000	625	30	16
2	250	375	500	8	$10\frac{1}{2}$	6	$2\frac{1}{2}$	6 2	21150	6980	23150	535	34	28
3	300	450	500	11	8	6	6	6 11	35000	10030	37800	500	37	32
4	400	600	500	13	4	6	9	7 5	38000	11270	41000	465	40	40
5	500	750	500	14	$4\frac{1}{2}$	7	$11\frac{1}{4}$	7 6	64800	12900	68500	375	48	48
6	700	1050	500	15	2	8	3	8 9	70100	14859	74100	300	60	56

Direct Connected Generators.

THERE are several advantages which may be secured by coupling the armature of a railway generator directly to the shaft of the driving engine, but to do this it is of course necessary to so construct the generator that its speed of revolution shall be as low as that of the engine. The speed, however, is an important factor in determining the out-put, and it is impossible to reduce the speed of the dynamo without increasing the weight, if the out-put is to be kept the same. Evidently, therefore, the cost of a direct connected generator will be somewhat greater than that of a high speed machine of the same capacity, but, in many cases, the saving effected in real estate, buildings, countershafting, belts, belt-tighteners, etc., will more than compensate for this difference, to say nothing of the greater economy in the operation of a plant where the losses due to friction of bearings and transmission of energy are reduced to the lowest possible point.

The advantages of a direct connected generator are briefly enumerated as follows:

Economy of floor space; meaning a smaller building for a given generating capacity; or, at least, double capacity for a given building.

The absence of the noise which accompanies the use of belts, and which absolutely prohibits their employment in city stations surrounded by dwelling houses.

A great reduction in the frictional load. A belt consumes between 5 and 10 per cent. of the total energy of an engine.

A reduction in the cost of maintenance, for the belt account disappears entirely and the oil and babbitt accounts are cut down.

The elimination of all danger to life or property resulting from belts breaking, or leaving their pulleys.

The cut, figure XI, represents one of our generators coupled direct to a Westinghouse Engine. The generator is thoroughly insulated from the bed-plate by a sheeting of tarred plank, the bolts being insulated by bushings and washers of non-conducting material. The insulation is completed at the coupling in which non-conducting material is interposed to prevent the possibility of metallic contact. The coupling is so designed that it will yield fully to any misalignment of the two shafts, either as to angle or position of centres, and at the same time ease the effect of the jar which otherwise results when a generator is short-circuited.

We manufacture multipolar generators for direct connection to any quick governing engine, or water-wheel, of any speed, and up to 5000 horse power capacity. The following table refers to our standard, multipolar, direct connected machines:

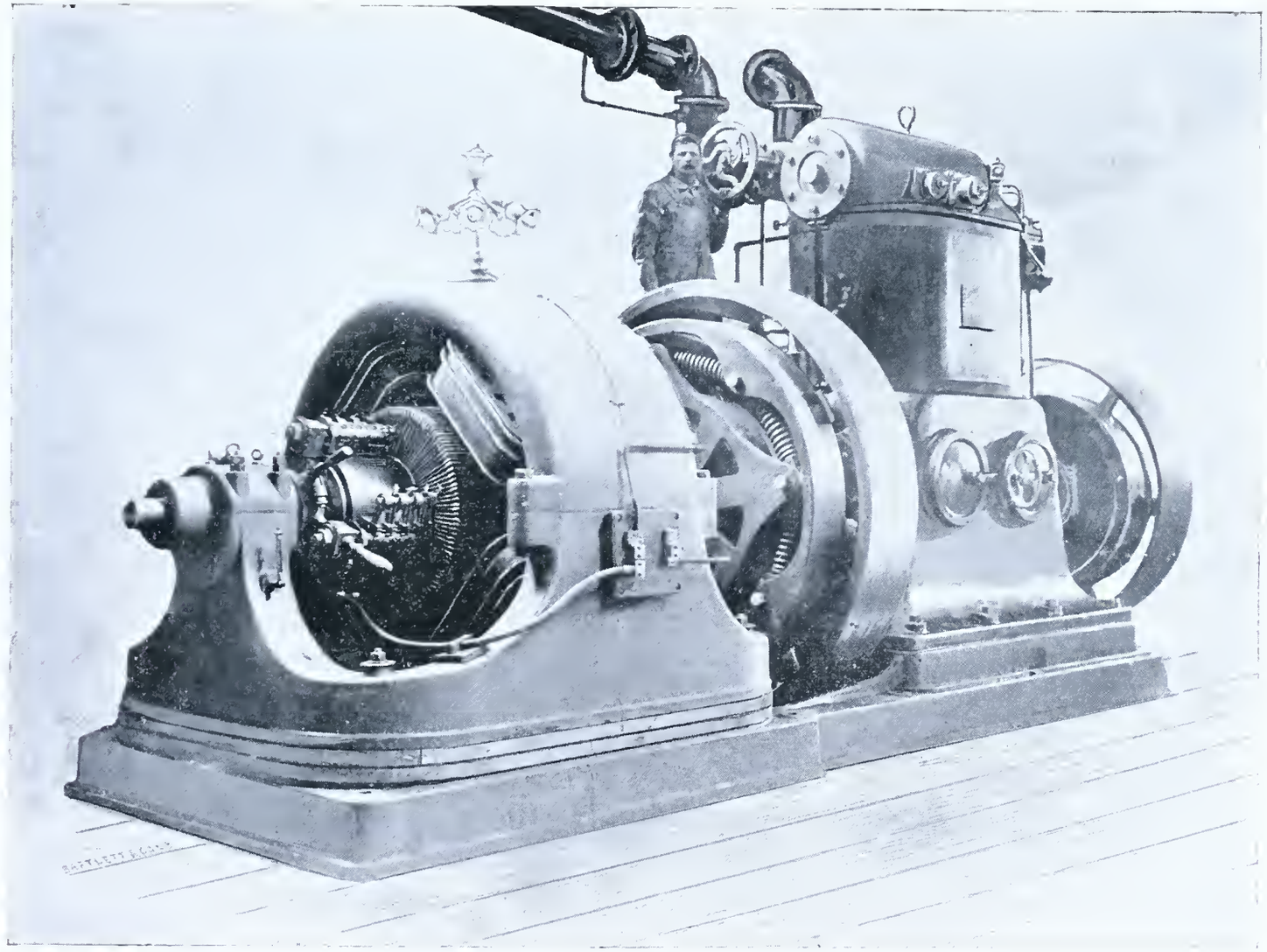

FIG. XI. MULTIPOLAR RAILWAY GENERATOR DIRECT CONNECTED TO WESTINGHOUSE ENGINE.

MULTIPOLAR DIRECT CURRENT DIRECT-CONNECTED GENERATORS.

Machine.	Capacity.	Output.		Dimensions of Generator.						Weight of Generator in Pounds. (Without Bed-Plate.)			Speed.
500 Volt D. C. Generator.	Horse Power.	Amperes.	Volts.	Length of Shaft.		Width of Bed-Plate.		Height Over Eyebolt.		Net.	Largest Gross Piece.	Gross Boxed for Shipment.	R. P. M.
No.				Ft.	Ins.	Ft.	Ins.	Ft.	Ins.				
1	100	150	500	7	$5\frac{3}{8}$	5	5	6	1	14500	4900	16000	300
2	160	240	500	8	$3\frac{3}{16}$	5	7	6	$5\frac{3}{4}$	18800	6980	20750	300
4	270	405	500	9	4	7	$0\frac{1}{2}$	7	$11\frac{1}{2}$	33100	11270	36100	250
6	500	750	500	9	10	8	8	9	0	61500	14860	65500	215